Advisory
Circular
U.S. Department of Transportation
Federal Aviation Administration

Subject: HALOCARBON HAND FIRE EXTINGUISHERS FOR USE IN AIRCRAFT TO REPLACE HALON 1211

Date: mm/dd/2005

AC No: 20-42XX

Initiated By:

NOTICE: An asterisk (*) following the number designating a paragraph indicates that explanatory material on the paragraph can be found in appendix A.

X. Scope. This Advisory Circular (AC) contains minimum requirements for halocarbon hand extinguishers, intended to replace halon hand extinguishers onboard aircraft. Guidance for the use of Halon 1211, Halon 1301, water, dry powder, and carbon dioxide hand fire extinguishers can be found in AC No. 20-42C.

CHAPTER 1. PURPOSE.

This advisory circular provides methods acceptable to the Administrator for showing compliance with the hand fire extinguisher provisions in Parts **21,** 25, 29, 91, 121, 125, 127, and 135 of the Federal Aviation Regulations (FARs)for Halocarbon extinguishers intended to replace halon 1211 hand-held extinguishers. These FARS refer to “halon 1211 or equivalent”. This circular names the halocarbons HCFC Blend B, HFC-227ea, and HFC-236fa as acceptable equivalents to halon 1211. Extinguishers with these agents have passed the required fire tests. This circular also provides new guidance for selection and use of these extinguishers.

The information in this AC is considered acceptable for use by the owners/operators of small aircraft. This AC is intended for use by those responsible for selecting, purchasing, installing, approving, and maintaining hand fire extinguishers and for those responsible for training personnel in their use.

This AC does not constitute a regulation and is not intended to require anything beyond what is specifically required by the regulations. Requirements are contained within the FAA Administrator’s Policy Letter referenced in Chapter 6, Approvals and Requirements for Hand Fire Extinguishers.

CHAPTER 2. FOCUS.

The halon 1211 replacement halocarbon agents in this advisory circular were introduced in response to restrictions on the production of ozone-depleting halon fire extinguishing agents under the Clean Air Act Amendments of 1990 which implemented the Montreal Protocol signed September 16, 1987, as amended. The need to switch to environmentally safe fire extinguishers and the availability of approved hand-held extinguisher models containing the

halocarbons HCFC Blend B, HFC-227ea and HFC-236fa require that a new AC be issued for the halon 1211 replacement halocarbon hand-held extinguishers.

This AC provides guidance for the fire-fighting effectiveness and safe use of halocarbon hand-held extinguishers intended to replace Halon 1211 hand-held extinguishers in transport category aircraft, as well as general guidance.

Safe-use guidance is provided to minimize the risk for adverse health effects (cardiac sensitization and anesthetic effects)from potential exposure to an agent. This guidance minimizes exposure to low oxygen concentrations that can result from the discharge of these agents in small aircraft. This safe use guidance is science-based, and is more accurate than that used for the halons in AC No. 20-42C.

HCFC Blend B, HFC227ea, and HFC 236fa are safe, acceptable alternatives to Halon 1211 that provide equivalent fire fighting performance, and meet the requirements outlined in this circular. Some of these agents can be safely used in much smaller aircraft than Halon 1211 while providing an equivalent level of fire protection.

CHAPTER 3. NEW ADVISORY CIRCULAR.

This advisory circular is intended to supplement AC 20-42C, Hand Fire-Extinguishers for use in Aircraft, dated, 3/7/1984 , which addresses Halon1211, Halon 1301, water, dry powder and carbon dioxide hand fire-extinguishers.

CHAPTER 4. RELATED REGULATIONS, DIRECTIVES, CIRCULARS, INFORMATION.

4.1 RELATED FAR SECTIONS AND CODE OF FEDERAL REGULATIONS (CFR).

4.1.1 FAR 21.305.

4.1.2 FAR 23.561.

4.1.3 FAR 25.561; 25.851; 25.857 (smoke containment requirement for cargo compartments)

25.851. States that
The following minimum number of hand fire extinguishers must be conveniently located and evenly distributed in passenger compartments:

Passenger Capacity	Number of Extinguishers
7 through 30	1
31 through 60	2
61 through 200	3
201 through 300	4
301 through 400	5
401 through 500	6
501 through 600	7
601 through 700	8

FAR 25.851 also specifies specific locations for extinguishers for the aircraft cabin, and for class A, B and E cargo/baggage compartments accessible to crewmember in-flight.

4.1.4 FAR 27.561.

4.1.5 FAR 29.561; 29.851; 29.853(e) and (f).

4.1.6 FAR 91.122 (altitude requirements)

4.1.7 ~~FAR 91.193(c)~~. *Could not find referenced section in FARs*

4.1.8 FAR 121.309(c).

4.1.9 FAR 125.119(b) and (c).

4.1.10 ~~FAR 127.107(c)~~ *Could not find referenced section in the FARs*

4.1.11 FAR 135.155.

4.1.12 CFR Title 46 and 49

4.1.13 CFR Title 40: Protection of the Environment, Part 82-Protection of Stratospheric Ozone, Subpart G-Significant New Alternatives Policy Program and Subpart H-Halon Emissions Reduction

4.2 RELATED ADVISORY CIRCULARS AND AIRWORTHINESS DIRECTIVES

4.2.1 AC 120-80 In-Flight Fires
4.2.2 AC 20-42C Hand Fire Extinguishers for Use in Aircraft
4.2.3 AD 93-07-15(2)(i) Airworthiness Directives; BOEING AND MCDONNELL DOUGLAS Models 707, 727, 737,747, and 757 and McDonnell Douglas Models DC-8, DC-9, and DC-10 Series Airplanes

4.3 RELATED DOCUMENTS

4.3.1 Webster, Harry, ”Development of a Minimum Performance Standard for Hand-Held Fire Extinguishers as a Replacement for Halon 1211 on Civilian Transport Category Aircraft”, Federal Aviation Administration Report No.DOT/FAA/AR-01/37

4.3.2 FAA Administrator’s Policy Letter for Handhelds ***(does not exist yet)***

CHAPTER 5. DEFINITIONS.

5.1 Halon. A short derivation for "halogenated hydrocarbon" whose chemical structure is identified as a four digit number representing, respectively, the number of carbon, fluorine, chlorine, and bromine atoms present in one molecule. Halon fire extinguishing agents approved for use include halon 1211, halon 1301, and a combination of the two). Both are liquefied gases and typified as "clean agents," leaving no agent residue after discharge and are electrically nonconductive. Halons primarily extinguish fire by chemically interrupting the combustion chain reaction rather than by heat removal or physically smothering.

5.2 Halon 1211. The chemical name is bromochlorodifluoromethane,

$CBrC1F_2$. Halon 1211 is a multipurpose, Class A, B, C rated agent effective against flammable liquid fires. Due to its relatively high boiling point (-4° C/+25° F), halon 1211 discharges as an 85 percent liquid stream offering a long agent throw range.

5.3 Hand Fire Extinguisher (Aircraft Hand Fire Extinguisher/Portable Fire Extinguisher). An approved, portable fire extinguisher as outlined in Section 6 of this AC, which can be used by aircraft occupants to combat accessible, incipient, on-board fires.

5.4 Halocarbon Agents. A halocarbon agent is an agent that contains as primary components one or more organic compounds containing one or more of the elements fluorine, chlorine, bromine, or iodine.Halocarbon agents include the halons and halon replacements. Halocarbon Agents that are currently commercialized include the hydrochlorofluorocarbons (HCFCs), perfluorocarbons (FCs or PFCs), hydrofluorocarbons (HFCs), fluoroiodocarbons (FICs), and fluoroketones (FKs), as well as the completely halogenated halocarbons (Halons).

Halocarbon Agents are electrically non-conducting, volatile liquids, or gaseous fire extinguishants. As clean agents, they do not leave a residue on evaporation. These agents are pressurized with inert gases. Halocarbon Agents SNAP approved for use on aircraft to replace Halon 1211 in hand fire extinguishers include HCFC Blend B, HFC-227ea, and HFC-236fa.

Halocarbon Agents are multipurpose class A, B, C rated agents. They have their greatest effectiveness on Class B and C fires. Extinguishers with greater capacity are also UL listed for Class A fires. To achieve the minimum 1A UL listing, one of the tests required is the extinguishment of an eight feet wide by eight feet tall wood panel. While smaller extinguishers do not contain a sufficient amount of agent to extinguish this size of fire, they have been shown to be effective against smaller Class A fires, such as seat fires onboard aircraft. Detailed information on agent characteristics, concentration requirements, health hazards, and extinguishing limitations may be obtained by consulting the agent manufacturers.

Advantages of halocarbon agents are low cold shock characteristics on electronic equipment, no degradation of visual acuity, and low pressure.

5.6 HCFC Blend B. This extinguishing agent is a tertiary blend comprised primarily of the chemical 2,2-dichloro-1,1,1-trifluoroethane HCFC-123, (CF_3CHCl_2). Two inert gases are blended with the HCFC-123 to enhance flow distribution and fire extinguishing performance. The boiling point of the blend is 80.6°F (27°C). Due to it's high boiling point, HCFC Blend B discharges primarily as a liquid stream which readily evaporates

5.7 HFC-227ea . This extinguishing agent is comprised of the chemical 1,1,1,2,3,3,3-heptafluoropropane (CF3CHFCF3). The boiling point of the agent is 2.5°F (-16.4°C). Due to this boiling point, HFC-227ea is discharged as a mixed liquid and vapor stream which readily evaporates.

5.8 HFC-236fa. This extinguishing agent is comprised of the chemical 1,1,1,3,3,3 hexafluoropropane ($CF_3CH_2CF_3$). The boiling point of the agent is +29.5° F (-1.4° C). Due to its relatively high boiling point), HFC-236fa discharges predominately as a liquid stream which readily evaporates.

5.9 Lowest Observable Adverse Effect Level (LOAEL). The lowest concentration at which an adverse physiological or toxicological effect has been observed.

5.10 No Observed Adverse Effect Level (NOAEL). The highest concentration at which no adverse physiological or toxicological effect has been observed.

5.11 Physiologically Based Pharmocokinetic(PBPK) Model. A mathematical modelling technique for human health risk assessment and investigation of toxicity. The PBPK model referenced in this circular the human arterial blood halocarbon concentration as a function of human exposure time to that halocarbon. Cardiac sensitization occurs at a fixed arterial concentration for each halocarbon. The PBPK modeling approach is endorsed by the US EPA and the National Fire Protection Association (NFPA).

5.12 Halon Replacement. ”Replacements” denote halocarbon agents intended to replace Halon 1211.

CHAPTER 6. APPROVED HAND FIRE FXTINGUISHERS.

Hand fire extinguishers are acceptable under FAR Sections 25.851(a)(1), 29.851(a)(1), 121.309(c), 127.107(c) and 135.155 if they have been approved in accordance with FAR 21, Section 21.305. In accordance with Section 21.305(d) of the FAR, the Federal Aviation Administration (FAA) accepts hand fire extinguishers approved in a manner equivalent to Underwriters' Laboratories, Inc. (UL), Factory Mutual Research Corp. (FM), or approved by the U.S. Coast Guard under Title 49 of the CFR for use in aircraft.

In accordance with Far 21, Section 21.305, FAA advisory circulars are one means for approval of hand fire extinguishers. Nothing in this AC is intended to restrict new technologies or alternate arrangements provided that the level of safety prescribed by this AC is not lowered.

Although Parts 91 and 125 do not require FAA approval of hand fire extinguishers, the information in this AC is considered acceptable for use by Parts 91 and 125 operators.

Operators of non-transport category aircraft should become familiar with the information in this AC and the precautions listed in paragraph **8.3.1**. In addition, the recommendations of the extinguisher manufacturer should be considered.

Any agent that is to be recognized by this AC or proposed for inclusion in this AC shall first be evaluated in a manner equivalent to the process used by the U.S. Environmental Protection Agency’s Significant New Alternatives Policy (SNAP) program in accordance with the CFR Title 40, Part 82, Subpart G. Agents covered by this circular have been reviewed and approved by SNAP as acceptable halon replacements.

The minimum safe cabin volumes of spaces to be protected by Halocarbon extinguishers in this AC may be smaller than allowed by SNAP and Underwriters Lab (UL), Inc. This FAA safe weight/volume guidance supercedes UL and SNAP guidance in this area. The reasons for this higher safety standard for aircraft are: 1) the inability for passengers to escape from an aircraft when airborne,

and 2)release of the contents of an extinguisher into the rarified (less dense) air at altitude results in a higher toxic hazard than a sea level release. 3) halocarbon agents are much heavier than air and stratify with time, causing potentially high concentrations in the forward section of the aircraft in steep descent.

Halocarbon Clean Agent extinguishers intended to replace halon 1211 UL listed 5B:C size extinguishers onboard transport category aircraft should pass the Hidden Fire Test and The Seat Fire/Toxicity Test identified in Report No. DOT/FAA/AR-01/37 "Development of a Minimum Performance Standard (MPS) for Hand-Held Fire Extinguishers as a Replacement for Halon 1211 on Civilian Transport Category Aircraft". The fire test criteria specified in this MPS ensure that extinguishers to replace Halon 1211 will have equal fire fighting performance and an acceptable level of toxicity for thermal decomposition products of the agent. Guidance agent concentrations are provided in this circular only.

A policy letter from the FAA Administrator is the legal basis for the labeling, stamping and MPS testing requirements for Halocarbon hand-held extinguishers intended to replace halon 1211. Halocarbon replacement agents covered in this circular must meet the requirements outlined in the letter from the Administrator of the FAA. These are as follows:
1)UL listed 5 B:C extinguishers or equivalent EN3 listed handhelds must meet The Minimum Performance Standard for hand extinguishers.
2)A Permanent label must be affixed to the extinguisher identifying FAA approval for use on board commercial aircraft based on the MPS test results.
3)A permanent label must be affixed to the extinguisher stating the minimum safe volumes for that extinguisher's use in pressurized and unpressurized aircraft, based on the agent's maximum safe exposure W/V ratios provided in this circular. The listed volumes should be based on no ventilation..
4)The extinguisher label should reference this Circular (Advisory Circular No. 20-42xx)as containing safe use guidance for that extinguisher onboard aircraft.
5) The label should not cover any data stamped on UL listed extinguishers, since this would invalidate the UL listing.

Note that the UL and MPS fire tests are extinguisher dependent. The extinguisher design effects extinguisher performance. The user must use the FAA approval label and the UL listing, not the agent weight to select extinguishers for an aircraft.

Halocarbon Clean Agents HCFC-Blend B, HFC-227ea, and HFC-236fa have been reviewed and approved by the U.S. Environmental Protection Agency SNAP program for environmental and toxicological acceptability as halon replacements.

UL listed 5B:C HCFC Blend B, HFC-227ea, and HFC-236fa extinguishers that have passed the minimum performance standard for handheld extinguishers are commercially available.

CHAPTER 7. BACKGROUND.

7.1. TYPES OF FIRES.

To properly select an appropriate hand fire extinguisher for use in an aircraft, it is recommended that consideration be given to the following classes of fires (as defined in the National Fire Protection Association (NFPA) Standard 10) that are likely to occur:

7.1.1 Class A. Fires involving ordinary combustible materials, such as wood, cloth, paper, rubber, and plastics, by cooling the material below it's ignition temperature and soaking the material to prevent reignition.

7.1.2 Class B. Fires involving flammable liquids, combustible liquied, petroleum oils, greases, tars, oilbase paints, lacquers, solvents, alcohols, and flammable gases.

7.1.3 Class C. Fires which involve energized electrical equipment where the use of an extinguishing media that is electrically nonconductive is important.

7.1.4 Class D. Fires which involve combustible metals, such as magnesium, titanium, zirconium, sodium, lithium, and potassium require specfic extinguishing agents of the dry powder type. The recommendations of the manufacturer of those extinguisher should be followed because of the possible chemical reaction between the burning metal and the extinguishing agent. Never discharge Halocarbon Clean Agents or water on Class D (burning metal) fires. Halocarbon agents may react vigorously with the burning metal.

7.2. EXTINGUISHING AGENTS APPROPRIATE FOR TYPES OF FIRES.

The following extinguishing agents are recommended, as appropriate, for use on the types of fires specified below:

7.2.1 Water - Class A.

7.2.2 Halocarbon Agents - Class A, B, or C. Halocarbon Agents should not be used for class D fires.

7.3. NUMERAL RATINGS. Numerals are used with the identifying letters for extinguishers labeled for Class A and Class B fires. The "numeral" indicates the relative extinguishing effectiveness of the device on a given size fire. This is dependent on the agent, the capacity of the device, discharge times, and design features. For example, an extinguisher rated as UL 4A should extinguish about twice as much Class A fire as a UL 2A rated extinguisher On an extinguisher rated for Class B fires, the numeral rating precedes the letter "B". Numeral ratings are not used for extinguishers labeled for Class C or D fires. Extinguishers that are effective on more than one class of fires have multiple "numeral-letter" and "letter" classifications and ratings; for example, UL 5B:C.

CHAPTER 8: HALOCARBON CLEAN AGENTS REPACING HALON 1211.

8.1 SPECIFICATIONS.
For hand fire extinguishers employing Halocarbon Clean Agents replacing Halon 1211, the following ASTM Specifications apply:

8.11 HCFC Blend B should meet the requirements of ASTM

Specification ASTM D7122.

8.12 HFC-227ea should meet the requirements of ASTM Specification D6064.

8.13 HFC 236fa should meet the requirements of ASTM Specification D6541.

8.2* GUIDANCE FOR FIRE FIGHTING EFFECTIVENESS OF HALOCARBON EXTINGUISHERS

8.2.1 For occupied spaces on transport category aircraft, extinguishers employing Halocarbon Clean Agents, replacing Halon 1211, should have a minimum UL 5B:C or an equivalent listing, and not less than 8 seconds effective discharge time, and not less than an 8-foot (3 m) throw range. Longer throw ranges provide a significant advantage in fighting fires in large transport category aircraft.

8.2.2 Always provide the recommended number of hand held extinguishers with the proper UL rating, even in spaces where the toxicity guidelines are exceeded. The failure to extinguish a fire has catastrophic consequences for all occupants of that aircraft. Agent toxicity concerns are secondary to extinguishing the fire.

8.2.3 If toxicity guidelines are exceeded, select the least toxic extinguisher of the required UL listing and use only the amount necessary to extinguish the fire.

8.2.4 Do not substitute two smaller extinguishers for one extinguisher of the proper UL rating. The fire can grow quickly prior to the discharge of the second extinguisher.

8.2.5 Extinguish the fire immediately. Fires can grow exponentially with time.

8.2.6 Best results in fire fighting are generally obtained by attacking the base of the fire at the near edge of the, fire and progressing toward the back of the fire by moving the fire extinguisher nozzle rapidly with a side-to-side sweeping motion.

8.2.7 The effective discharge time of a UL 5B listed extinguisher is approximately 9 seconds, for a UL 1A:10B:C extinguisher, and 14 seconds for a UL 2A:10B:C extinguisher. Due to this relatively short effective time span, proper training and use of the fire extinguishers are important.

8.2.8 At close range, care must be taken not to direct the initial discharge at the burning surface at close range because the high velocity stream may cause splashing and/or scattering of the burning material.

8.2.9 Halocarbons that are gaseous upon discharge have a more limited throw range. Halocarbons have discharge characteristics dependent on the halocarbon, nozzle design, and extinguisher superpressurization. Throw ranges of 10 feet and higher provide significant advantages in fighting fires in large aircraft cabins.

8.2.10 Never discharge Halocarbon Clean Agents or water on Class D (burning metal) fires. These agents may react vigorously with the burning metal.

8.2.11 For access to underseat, overhead, and other difficult to reach locations, extinguishers equipped with a discharge hose or adjustable wand are advantageous. An extinguisher with a discharge hose or adjustable wand is more likely to result in the extinguisher being properly held in an upright position during use and provides a means of directing a stream of agent to more inaccessible areas. Adjustable wand or fixed nozzle extinguishers allow for one-handed use.

8.3* GUIDANCE FOR SAFE USE OF HALOCARBON EXTINGUISHERS

8.3.1 Precautions:

8.3.1.1 Exposure to halocarbon agents and their decomposition products is of far less concern than the consequences of an unextinguished fire which include: the loss of the aircraft and it's occupants, and an immediate toxic hazard from exposure to thermal decomposition products of the burning materials, including carbon monoxide, smoke, heat, and oxygen depletion.

8.3.1.2 The designer should make every effort to consider the effects of agent toxicity, ventilation, stratification and low oxygen hypoxia when selecting and sizing the necessary fire protection. This includes consideration of enhanced toxicity due to stratification into the cockpit for an aircraft in descent, as well as stratification of agent into lower level sleeping quarters while in-flight. Perfect mixing was assumed for the safe-use guidance in this AC.

8.3.1.3 For aircraft cabins that are smaller than the minimum safe volume for ***all*** the halocarbon extinguishers in the cabin, extinguishers with the least toxic halocarbon agent should be placed in the aircraft (see table 1 for guidance). Place warning label on the extinguisher to stop discharge as soon as the fire is extinguished.

8.3.1.4 If extinguishers exceeding the maximum safe weights are installed, use of protective breathing equipment is recommended.

8.3.1.5 Exposure to high levels of halocarbon vapors exceeding the amounts allowed in this AC may result in dizziness, impaired coordination, reduced mental acuity, and heart arrhythmias, depending on agent concentrations and the duration of exposure. See the Appendix of "NFPA Standard 2001 on Clean Agent Fire Extinguishing Systems" for more detailed information.

8.3.1.6 Ventilate the compartment promptly, overboard, if possible, after successfully extinguishing the fire. This will reduce the concentration of halocarbons, and the thermal decomposition gases. Follow fire fighting procedures for protective breathing apparatus.

8.3.1.7 Unnecessary exposure of personnel to halocarbon clean agent including at or below the recommended maximum safe exposure levels, and the halocarbon decomposition products shall be avoided. After extinguishing the fire, the aircraft should be ventilated at the highest possible rate to rid the cabin and cockpit of hazardous gases and smoke. Small unpressurized aircraft/ rotorcraft can increase ventilation significantly by opening windows, descending immediately at the maximum safe rate to an altitude of 8,000 feet or lower, if practicable. Protective breathing equipment should be used if available. Unprotected personnel should not enter a protected space during or after agent discharge, until ventilated.

8.3.1.8 Halocarbon agents decompose when subjected to flame or hot surfaces. The decomposition products of the halocarbon agents have a characteristic sharp, acrid odor, and an eye irritating effects, even in concentrations of only a few parts per million.

8.3.1.9 The minimum safe volumes for extinguishers in pressurized and unpressurized aircraft should be listed on a label permanently attached to each extinguishing bottle. The listed volumes should be based on no ventilation, even for aircraft with known ventilation. These aircraft minimum safe volumes are based on the safe use agent guidance in this circular. Minimum safe volumes for the following pressure altitudes should be listed: 8,000 ft (pressurized aircraft), 14,000 ft (unpressurized aircraft with no oxygen masks), and 18,000 ft. (unpressurized aircraft with nasal canulae oxygen assisted breathing). The listed aircraft minimum safe volumes have an inherent safety factor that assumes no ventilation and no stratification of the agent. Use the value for the highest altitude for which the aircraft is certified.

8.3.2* Guidance for Unventilated Passenger and Crew Compartments

Unventilated use guidance applies to compartments where the air change time of the is not known, or exceeds 6 minutes. Unventilated guidance should also be used if the ventilated aircraft selector graphs are not available for that agent in 8.3.3.

8.3.2.1 If halocarbon clean agent extinguishers are installed in a unventilated passenger or crew compartment, and the compartment cannot be vented, then the total agent available from all the hand held extinguishers onboard the aircraft should not be capable of producing concentrations in the compartment, by volume at 70 Deg F (21 Deg C), assuming perfect mixing, that exceeds the agent's safe exposure guidelines as indicated in Table 1. Note that the agent weight to be used is the total weight of agent contained in all hand-held extinguishers in the aircraft cabin. The basis for this table is discussed in section A8.3 of the appendix

8.3.2.2 The maximum safe agent weight per unit volume can be obtained from table 1. The tabulated values are based on the release of the halocarbon agents at 70°F: (21.1°C) at the stated pressure altitude into unventilated compartments. The minimum safe volume can be obtained by dividing the total weight of agent contained in all hand held extinguishers in the aircraft cabin by the tabulated weight/volume ratio for that agent. If toxicity guidelines are exceeded, select the least toxic halocarbon extinguisher of the required UL listing from this table.

le 1 Maximum Safe Agent Weight per Unit Volume for Halocarbon Extinguishers in Unventilated Aircraft

Agent	Maximum Safe Weight/Volume (pounds/ft^3)[a,b]

Agent	For Sea Level (For info only)	Pressurized Aircraft[c] (8,000ft. Pressure Altitude)	Non-Pressurized Aircraft[c,d] (14,000 ft. Pressure Altitude)	Non-Pressurized Aircraft[c,d] (18,000 ft. Pressure Altitude using nasal cannula oxygen)
HCFC Blend B	0.00389	0.00289	0.00229	0.00195
HFC-236fa	0.0579	0.0432	0.0342	0.0292
HFC-227ea	0.0532	0.0394	0.0313	0.0266
Halon 1211[e]	0.00450	0.0034[e]	0.00264[e]	0.00225[e]

a) Use this table if the air change time is unknown, or exceeds 6 minutes.
b) The total weight of agent for all extinguishers in the aircraft cabin is the basis for these maximum safe weight/volume ratios.
c) Ventilate the compartment immediately, preferably overboard, after successfully extinguishing the fire.
d) All Unpressurized aircraft should descend immediately at the maximum safe rate to an altitude that is as low as practicable.
e) This Halon 1211 data in this table uses the halocarbon extinguisher toxicity guidance provided in this circular. It is included in this AC for comparison purposes only.

8.3.2.3 For compartments that have some means of ventilation, ventilate immediately after agent discharged and fire is extinguished. Increase ventilation to the highest possible rate.

8.3.2.4 All unpressurized aircraft should descend immediately at the maximum safe rate to an altitude that is as low as practicable. This dilutes the agent concentration, lowering exposure to the halocarbon agent and combustion gases. [redacted]cent is necessary to avoid the life-threatening hazards of hypoxia, [redacted]sulting from the agent displacing oxygen.

8.3.2.5 Refer to precautions in section 8.3.1 for actions that personnel should take t limit exposure.

8.3.2.6 Health and safety advantages associated with small volume occupied spaces on larger aircraft (flight decks) do not usually exist for the smaller aircraft. These advantages are a forced ventilation system, availability of oxygen masks, and availability of a second individual capable of flying the aircraft.

8.3.2.7 Refer to the precautions section 8.3.1 for actions that personnel should take limit exposure.

8.3.3* Guidance for Ventilated Passenger and Crew Compartments

8.3.3.1 For ventilated compartments, the graphs shown in figures 1 and 2 can be used to find safe extinguisher sizes, when compartment volume and ventilation rates are controllable and known. If compartment volumes and ventilation rates are not k[redacted]n or if the air change time for the compartment exceeds 6 minutes, these selector graphs should not be used: Use tables 1 or 2 to ensure safe extinguisher sizes as described in 8.3.2.

These selector graphs are based on the assumption of perfect mixing. The weight to be used is the total weight of agent contained in all hand-held extinguishers in the aircraft cabin. Adherence to these graphs provides protection from agent toxicity. Both ventilation and descent are necessary to

avoid the life-threatening hazards of hypoxia, resulting from the agent displacing oxygen.

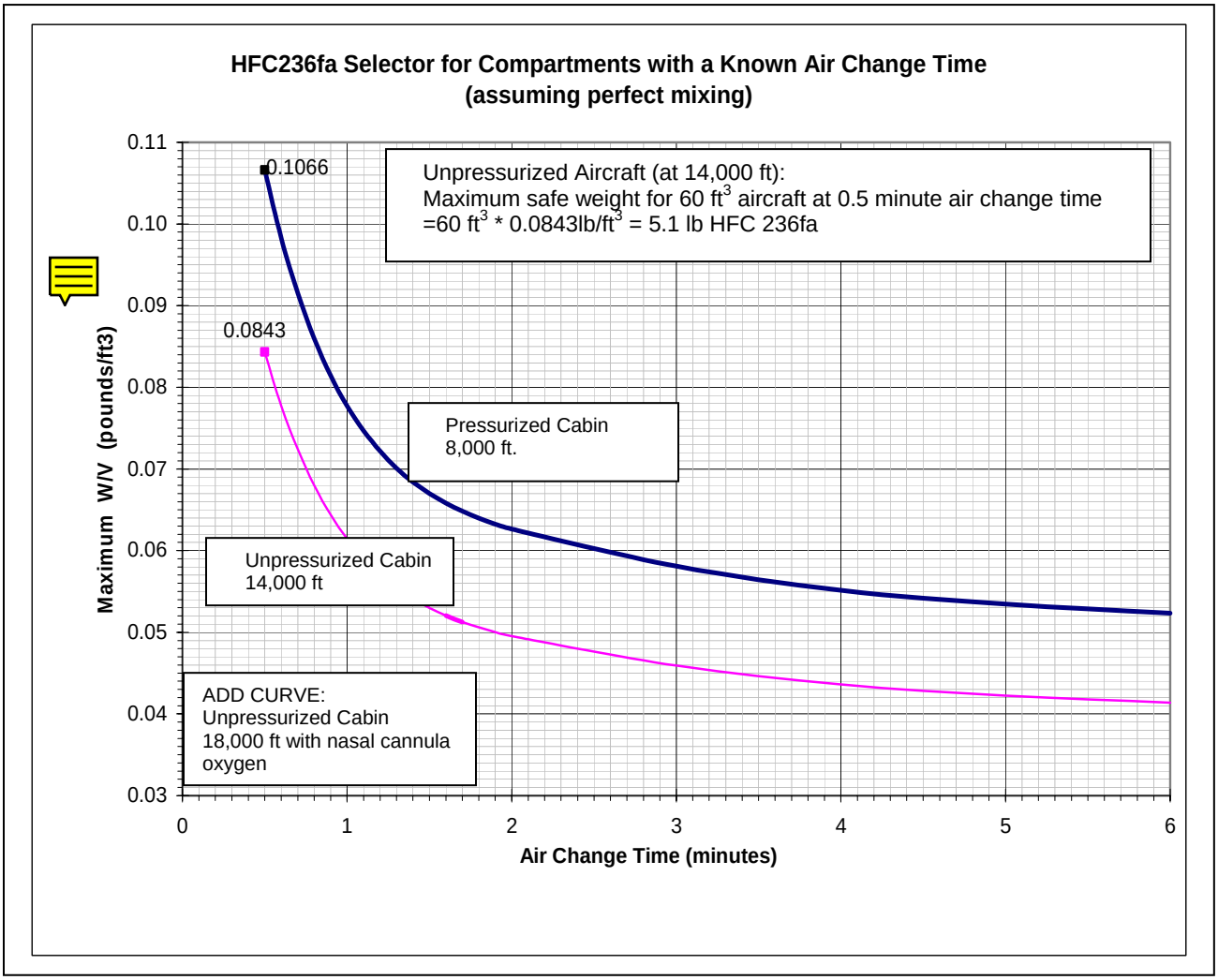
8.3.3.2 Ventilate immediately after the agent is discharged and the fire is extinguished. Increase ventilation to the highest possible rate, and turn off any air recirculation systems, if equipped.

8.3.3.3 Unpressurized aircraft should descend immediately at the maximum safe rate to the lowest practicable altitude to avoid the life-threatening hazards of hypoxia and to lower exposure to halogenated agents. (This guidance should be followed for ventilated as well as unventilated compartments). Pressurized aircraft benefit only from descent below 8,000 feet, although, it is not necessary.

8.3.3.4. Refer to the precautions section 8.3.1 for actions that personnel should take to limit exposure.

8.3.3.5 Health and safety advantages associated with small volume occupied spaces on larger aircraft (flight decks) do not usually exist for the smaller aircraft. These advantages are a forced ventilation system, availability of oxygen masks, and availability of a second individual capable of flying the aircraft.

Figure 1. HFC-236fa Selector for Compartments with a known Air Change Time



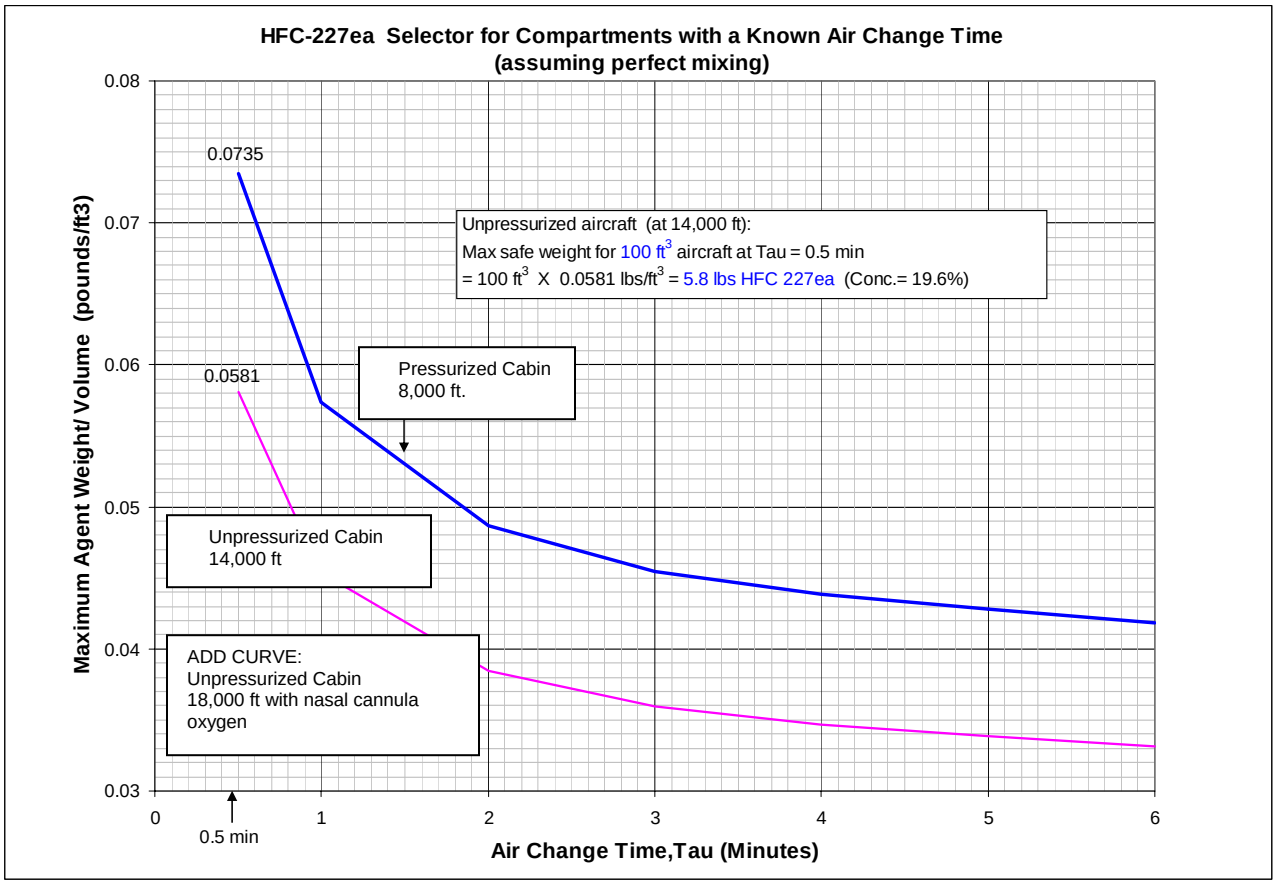
Ventilate immediately **after extinguishing fire.** Increase ventilation to the highest possible rate.

If airchange time is unknown, or exceeds 6 minutes, use maximum safe W/V ratios for unventilated aircraft (Prolonged exposure to these agents may be hazardous):

- W/V = 0.0432 pounds/ft^3 for Pressurized Cabins
- W/V = 0.0342 pounds/ft^3 for Nonpressurized Cabins
- W/V = 0.0292 pounds/ft^3 for Nonpressurized Cabins (18,000 ft. Pressure altitude if aircraft is equipped with nasal cannula oxygen supply

Unpressurized aircraft should descend immediately at the maximum safe rate to the lowest practicable altitude to avoid the life-threatening hazards of hypoxia and to lower exposure to halogenated agents

Figure 2. HFC-227ea Selector for Compartments with a known Air Change Time



Ventilate immediately **after extinguishing fire.** Increase ventilation to the highest possible rate.

If airchange time is unknown, or exceeds 6 minutes, use maximum safe W/V ratios for unventilated aircraft (Prolonged exposure to these agents may be hazardous):

- W/V = 0.0394 pounds/ft^3 for Pressurized Cabins (8,000 ft Pressue altitude)
- W/V = 0.0313 pounds/ft^3 for Nonpressurized Cabins (14,000 ft. Pressure altitude)
- W/V = 0.0266 pounds/ft^3 for Nonpressurized Cabins (18,000 ft. Pressure altitude if aircraft is equipped with nasal cannula oxygen supply

Unpressurized aircraft should descend immediately at the maximum safe rate to the lowest practicable altitude to avoid the life-threatening hazards of hypoxia and to lower exposure to halogenated agents

Note to Task Group:
The AC can be updated as new agents and new graphs are submitted to the FAA Transport Aviation Directorate.

8.3.4 Guidance for Accessible Cargo Compartments

8.3.4.1 For accessible cargo compartments, in combination passenger/cargo and cargo aircraft, the amount of halocarbon extinguishing agent required for this application may be outside the range of allowable exposures, and protective breathing equipment should be donned before entering the compartment.

8.3.4.2 FAR 25.857 requires that the aircraft systems are designed such that unsafe concentrations of extinguishing agent, for fighting accessible cargo compartment fires, will not enter the cabin. Nonetheless, the cargo compartment door should be closed after extinguishing the fire.

8.3.4.3 For accessible cargo compartments, in combination passenger/cargo and cargo aircraft, smaller than 200 cubic feet, which are not protected by fire protection flooding systems, in combination passenger/cargo and cargo aircraft, halocarbon clean agent extinguishers should have a listed classification not less than UL 2A:10B:C.

8.3.4.4 Accessible cargo compartments of 200 cubic feet and larger, in combination passenger/cargo and cargo aircraft, should meet the requirements of the FAA Airworthiness directive 93-07-15. Note that this AD specifies acceptable forms of fire protection as an option to the use of hand-held fire extinguishers. These options include converting that compartment to meet the requirements of a class C cargo compartment or the use of fire containment containers or covers.

8.3.4.5 The AD 93-07-15 requirements for portable fire extinguishers include:(i)The AD recommends the use of Halon 1211 or it's equivalent and water portable fire extinguishers for fire protection of accessible cargo compartments. Halon1211 equivalency is met as follows: Provide a minimum of three UL listed 2A:10B:C extinguishers (equivalent to the AD's requirement of 48 lbs. Halon 1211) in portable fire extinguishers readily available for use in the cargo compartment. (ii) AD 93-07-15 also requires the provision of at least two Underwriters Laboratories (UL)2A (2-1/2 gallon) listed water portable fire extinguishers, or its equivalent, adjacent to the cargo compartment entrance for use in the compartment. (iii) Provide a minimum of 30 minutes of protective breathing. This equipment must meet the requirements of Technical Standard Order (TSO) C-116, Action Notice 8150.2A, or equivalent, and be stored adjacent to the cargo compartment entrance.

8.3.4.6 Extinguishers (mounted alongside the entrance to the cargo compartment) intended for use to fight cargo fires in accessible cargo compartments in combination passenger/cargo and cargo aircraft, should be available to extinguish cabin fires. Select an extinguisher for that accessible cargo compartment that meets the safe exposure guidance for the aircraft cabin. It should not exceed the maximum safe weight for the aircraft cabin.

If no extinguisher, intended for use to fight fires in accessible cargo compartments, is available that meets the safe nontoxic use criteria for the aircraft cabin, consider converting that cargo compartment to a class C compartment with a fire suppression system, or any other technology that would provide effective fire protection. Provide means to restrict personnel from entering the cargo compartment for the flight duration.

If no extinguisher, intended for use to fight fires in accessible cargo compartments, is available that meets the safe exposure guidance for the aircraft cabin, do not use an extinguisher with a lower UL Rating than recommended for the cargo compartment. Select the least toxic extinguisher of the required rating (the extinguisher that can be used most safely, if it was used in the cabin).

If the contents of the extinguisher exceed the maximum safe exposure levels for the cabin, place a warning on or alongside the extinguisher stating: "Discharge of the entire contents of this size extinguisher into the occupied cabin area exceeds safe exposure limits. Use only the amount necessary to extinguish a fire."

8.3.4.7 Refer to the Precautions section 8.3.1 for actions that personnel should take to limit exposure.

CHAPTER 9. LOCATION AND MOUNTING OF HAND FIRE EXTINGUISHERS.

9.1 LOCATION AND MOUNTING OF HAND FIRE EXTINGUISHERS IN PASSENGER COMPARTMENTS.

It is acceptable to install fire extinguishers in passenger compartments according to the following criteria:

9.1.1 In general, locate hand fire extinguishers adjacent to the hazardous area (i.e., galleys, accessible baggage or cargo compartments, electrical equipment racks, etc.) they are intended to protect.

9.1.2 If no clearly defined hazardous area exists, locate the hand fire extinguishers as follows:

9.1.2.1 When one extinguisher is used, locate it at the flight attendant's station or, when no flight attendant is required, locate the extinguisher at the passenger entrance door.

9.1.2.2 When two or more extinguishers are used, locate one at each end of the passenger compartment and space the remainder uniformly within the cabin area.

9.1.3 Mount hand fire extinguishers so that they are readily available. If they are not visible in their mounted position, a placard (with letters at least 3/8-inch high) may be used to indicate their location.

9.1.3.1 Due to the weight of hand fire extinguishers, the aircraft structure and extinguisher mounting brackets should be capable of withstanding the inertia forces required in Sections 23.561, 25.561, 27.561, and 29.561 of the Federal Aviation Regulations, with the hand fire extinguisher installed. In addition, the operational and crash safety shock environments specified in the current version of RTCA DO160 should be considered. If extinguishers are replacing halon extinguishers, the mounting system may need to be strengthened, as the halocarbon extinguishers are much heavier than halon extinguishers. Evaluate the mounting system to make sure it is adequate.

9.1.3.2 Halocarbon clean agent extinguishers of the same listing can be twice the weight of the Halon extinguishers they are replacing. (Installation of an extinguisher should include vertical reach combined with horizontal (offset)

reach to ensure ease of retrieval from overhead compartments. The vertical reach should not exceed 74.5 in. (189.23 cm) combined with an offset reach of 7.87 in. (20cm) to permit a 5 percentile female, 60.5 in. (153.67 cm.) tall to quickly access the extinguisher.

9.1.3.3 The weight of the hand fire extinguisher and its mounting bracket should be added to the aircraft empty weight and a new empty weight center of gravity computed.

9.1.4 Fire extinguisher selection should be made with consideration of the type of fire hazard (Class A, B, C) to be encountered. If extinguishers intended for different classes of fire are grouped together, their intended use should be marked conspicuously to aid in the choice of the proper extinguisher at the time of the fire.

9.2 LOCATION AND MOUNTING OF HAND FIRE EXTINGUISHERS IN SMALL SINGLE ENGINE AND MULTIENGINE AIRCRAFT.

9.2.1 Locate hand fire extinguishers so that they are easily accessible to the flight crew and the passengers.

9.2.2 Hand fire extinguishers should not he allowed to lie loose on shelves or seats. Fire extinguishers and mounting brackets should be properly mounted to the airframe structure and be capable of withstanding the inertia forces
required by the FAR sections listed in paragraph 9.1.3.1 of this AC.

CHAPTER 10. GENERAL INFORMATION

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10.1 CORROSION BY EXTINGUISHING AGENTS.
Halocarbon Clean Agents are not corrosive, but material compatibility properties should be reviewed for acceptability to aircraft materials. Water itself is not corrosive, but may be rendered corrosive by the addition of antifreeze solutions.

10.2 MATERIAL COMPATABILITY .
Halocarbon clean agents can be used in numerous aircraft applications and it is important to recview the materials of construction for compatibility when designing new equipment, retrofitting existing equipment, or preparing storage and handling equipment to incorporate halocarbon clean agents. Materials that should be considered include metals, elastomers, and plastics.

10.3 OPERATING TEMPERATURE REQUIREMENTS FOR HALOCARBON CLEAN AGENT HAND FIRE EXTINGUISHERS.
The extinguisher should operate properly after being conditioned at minus 40°F or minus 65°F as applicable and 120°F for 16 hours as specified in UL 2129.

10.4 FACTORY SEALED ("DISPOSABLE TYPE") FIRE EXTINGUISHERS.

10.4.1 Disposable type fire extinguishers should be maintained and inspected in accordance with the nameplate instructions.
10.4.2 Nonrefillable disposable fire extinguishers have plastic discharge heads installed. Care should he exercised in the location of this type of fire extinguisher to eliminate damage.
Are there any water or halon disposable extinguishers on aircraft?

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10.4.3 Nonrefillable disposable fire extinguishers are exempt from the periodic hydrostatic test requirements.

10.5 INSPECTION, HYDROSTATIC TEST AND LIFE LIMITS.

Recommended procedures for the inspection, hydrostatic test and life limits of pressure cylinders are outlined in Part 173, Chapter 1, Subparts B, and G of CFR 49 currently in effect. See CFR 49, Part 173.306(c) (5) regarding retest intervals for fire extinguishers.

CHAPTER 11. RELATED RESEARCH MATERIAL

- UL2129 Halocarbon Clean Agent Fire Extinguishers, ISBN 0-7629-0408-9, Copyright 2000, Underwriters Laboratories Inc.
- NFPA 10 Standard for Portable Fire Extinguishers, Copyright 1998 NFPA
- Webster, Harry, "Development of a Minimum Performance Standard for Hand-Held Fire Extinguishers as a Replacement for Halon 1211 on Civilian Transport Category Aircraft", Federal Aviation Administration Report No.DOT/FAA/AR-01/37
- Hill, R.G., and Speitel, L., "In-Flight Aircraft Seat Fire Extinguishing Tests(Cabin Hazard Measurements)", Federal Aviation Administration Report No. DOT/FAA/CT-82/111, , December 1982
- Halon Extinguishment of Small Aircraft Instrument Panel Fires, DOT/FAA/CT-86/26, Slusher, G.R., Wright, J.A., and Speitel, L.C., December 1986
- NFPA 408, Standard for Aircraft Hand Portable Fire Extinguishers, 1999 Edition
- NFPA 12B Standard on Halon 1211 Fire Extinguishing Systems, 1990 Edition
- NFPA 2001 Standard on Clean Agent Fire Extinguishing Systems, 2004 Edition, National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts, Feb. 2004.
- Vinegar, A., Jepson, G.W. and Overton, J.H (1998): PBPK Modeling of Short-term (0-5 min) Human Inhalation Exposures to Halogenated Hydrocarbons, Inhalation Toxicology, 10:411-429.

  Note: This is an early document, which provides human validation data for the PBPK approach and provides detailed mathematical descriptions of the respiratory component of the PBPK model. This document also has an example of Halon 1211 release in a military tank and the evaluation of the exposure and consequences using PBPK modeling.
- Vinegar, A., Jepson, G.W., Cisneros, M., Rubenstein, R. and Brock, W.J. (2000): Setting Safe Acute Exposure Limits for Halon Replacement

Chemicals Using Physiologically Based Pharmacokinetic Modeling, Inhalation Toxicology, 12:751-763.

Note: This is the document that provides the basis for the tables in NFPA 2001 (2000 edition). It also provides safe exposure data for Halon 1301, which is not shown in NFPA 2001. It is interesting to note using the PBPK modeling approach, Halon 1301 cannot be safely used at concentrations above 6% v/v for more than 5 minutes.

- Vinegar, A (2001): Modeling Cardiac Sensitization Potential of Humans Exposed to Halon 1301 or Halon 1211 Aboard Aircraft, Aviation, Space and Environmental Medicine, Vol. 72, No. 10.

  Note: This paper illustrates Halon 1301 and Halon 1211 application aboard aircraft and compares the predicted human blood levels to cardiac sensitization. While predicted Halon 1301 blood levels did not exceed cardiac sensitization thresholds, Halon 1211 levels did exceed the thresholds in several areas.

- Vinegar, A., Jepson, G.W., Hammann, S.J., Harper, G., Dierdorf, D.S. and Overton, J.H.(1999): Simulated Blood Levels of CF_3I in Personnel Exposed During Its Release from an F-15 Jet Engine Nacelle and During Intentional Inhalation, AIHA Journal, 60:403-408.

  Note: This paper establishes the precedent of predicting human blood levels of agent during conditions of changing exposure concentration. This sort of an approach would be required to accommodate perfect mixing decay curves for various air change rates

- Webster, Harry, "Development of a Minimum Performance Standard (MPS) for Hand-Held Fire Extinguishers as a replacement for Halon 1211 on Civilian Transport Category Aircraft" Federal Aviation Administration Report No.DOT/FAA/AR-01/37, 2002

- Eklund, Thor I. "Analysis of Dissipation of Gaseous Extinguishing Agents in Ventilated Compartments"
  Federal Aviation Administration Report No. DOT/FAA/CT-83/1, 1993.**Note:** This report develops the calculation of agent dissipation as a function of time using the perfect stirrer model. It also describes the theory and assumptions used in the development of the nomographs for the Halons.

- Speitel, Louise C. "Setting Safe Acute Exposure Limits for Dissipating Gaseous Halon and Halocarbon Extinguishing Agents in Ventilated Compartments" Federal Aviation Administration: Report to be published. **Note:** This report provides a simple first order pharmacokinetic solution for changing concentrations of halocarbons.

- Slusher, Gerald R., Wright, Joseph, Demaree, James, "Halon Extinguisher Agent Behavior in a Ventilated Small Aircraft", Federal Aviation Administration Report No. DOT/FAA/CT-86/5, 1986

- Slusher, G.R., Wright, J., Demaree, J.E., Neese, W.E. "Extinguisher Agent Behavior in a Vantilated Small Aircraft, Federal Aviation Administration Report No. DOT/FAA/CT-83-30,1984

- Abramowitz, A., Neese, W., Slusher, G, "Smoke and Extinguisher Agent Dissipation in a Small Pressurized Fuselage" Federal Aviation Administration, Report No. DOT/FAA/CT-89/31, 1990.

- Krasner, L.M. "Study of Hand-held Fire Extinguishers aboard Civil Aviation Aircraft" Factory Mutual Research Corporation, Federal Aviation Administration Report No. DOT/FAA/CT-82/42, 1982

  Note: This report reviews human exposure data for Halon 1211 and 1301

- Chattaway,A. "The Development of A Hidden Fire Test for Aircraft Hand Extinguisher Applications", Civil Aviation Authority Paper No. 95013, London, 1995.

  Note: This report describes the development of the hidden fire test for hand-held extinguishers.

- CFR Title 40: Protection of the Environment, Part 82-Protection of Stratospheric Ozone, Subpart G-Significant New Alternatives Policy Program and Subpart H-Halon Emissions Reduction
- Cherry, R.G. W. et al, "A benefit Analysis for Enhanced Protection from Fires in Hidden Areas on Transport Aircraft", Federal Aviation Administration Report No. DOT/FAA/AR-02/50, CAA Paper 2002/01.

- Blake, D.R. "Effectiveness of Flight Attendants Attempting to Extinguish Fires in an Accessible Cargo Compartment", Federal Aviation Administration Technical Note DOT/FAA/AR-TN99/29, 1999

CHAPTER 12. HOW CAN I OBTAIN FAA PUBLICATIONS

Contact the National Technical Information Service, Springfield, Va 22161

FAA publications can also be found on the following Web Site of the FAA Fire Safety Branch:
http://www.fire.tc.faa.gov/reports/

APPENDIX A Explanatory Material

Appendix A is not a part of the guidance of this advisory circular but it is included for information purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.

A-8.2 EFFECTIVE THROW RANGES

Table A1. Effective Throw Ranges for Halocarbon Halon Replacement and Water Extinguishers*

Agent	Effective Throw Ranges for UL/ULC Rated Extinguishers			
	5-B:C	1A-10 B:C	2A	2A-10 B:C
HCFC Blend B	9 - 15 ft.	9 - 15 ft.		12 - 18 ft.
HFC-236fa	10- 12 ft.	14- 16 ft.		14-16 ft.
HFC-227ea	**8- 10 ft**	N/A		N/A
Water			30-40 ft.	

* Check with extinguisher manufacturer for actual throw range, as it depends on the nozzle design and other factors: It is extinguisher dependent.

A-8.3 GUIDANCE FOR SAFE USE OF HALOCARBON EXTINGUISHERS

Following the guidance in either table 1 or the selector curves protects against the toxic effects of the halocarbon agent only, not hypoxia. Life-threatening hypoxic (low oxygen) hazards are avoided by immediate descent to a minimum rate of 1,000 ft/ minute to the lowest practicable altitude. The maximum agent concentrations allowed in this document result in hypoxic environments for both ventilated and unventilated aircraft. Immediate descent at the required descent rate is necessary to avoid hypoxia hazards. A descent to 8,000 ft is desirable to minimize the hypoxic hazard for the highest allowed agent concentrations (see table 1 and figures 1 and 2).

A-8.3.2 BASIS FOR THE MAXIMUM SAFE HALOCARBON WEIGHT TO VOLUME RATIOS

The maximum safe halocarbon exposure concentration protects against the agent toxicity which includes both cardiotoxicity and anesthetic effects (not low oxygen hypoxia). Cardiac sensitization occurs before anesthetic effects are observed for each of the halon replacement agents in this circular: HCFC Blend B, HFC-227ea and HFC-236fa.

The science behind this toxicity guidance is based on the cardiotoxicity. The cardiotoxicity evaluation is based on pharmacokinetic (PBPK) modeling which relates the arterial blood halocarbons concentration histories to the inhaled halocarbon concentration histories. Each halocarbon agent has a threshold arterial blood concentration at which cardiac sensitization occurs. The detailed scientific basis for the cardiotoxicity evaluation is found in the articles in the reference section of this circular.

Note:The maximum safe exposure concentration alone does not protect against low oxygen hypoxia. The recommended descent rates, combined with the safe use guidance provides protection against low oxygen hypoxia.

The basis for the agent toxicity guidance is as follows:
If halocarbon clean agent extinguishers are installed in a unventilated passenger or crew compartment, and the compartment cannot be vented, and the occupants cannot leave if the extinguishers are discharged, then the total agent available from all the hand held extinguishers on-board the aircraft should not be capable of producing concentrations in the compartment, by volume at 70 Deg F (21°C) assuming perfect mixing, that exceeds the agent's safe exposure guidelines as indicated by its pharmacokinetic(PBPK) derived 5 minute safe human exposure concentration, if known (Table A2). Otherwise, If PBPK data is not available, the Agent No Observable Adverse Effect Level (NOAEL) is to be

used (Tale A2). Exposures to halocarbon agents must be limited to less than 5 minutes (to protect against potential anesthetic effects which can result from prolonged exposure to halocarbon agents).

Table A2. Maximum Safe Exposure Concentrations for Unventilated Compartments and Compartments where the Ventilation is not Known

Agent	Maximum Safe 5 minute Human Exposure[a,b,c] Concentration (%v/v)	NOAEL[b,c,d] (%v/v)	FAA Guidelines: Maximum Safe Exposure Concentration (%v/v)
HCFC Blend B	unknown	1.0[e]	1.0[f]
HFC -227ea	10.5	9.0	10.5[f]
HFC-236fa	12.5	10.0	12.5[f]
Halon 1211[g]	1.0	0.5	1.0[g]

a) Data derived from the EPA-approved and peer reviewed PBPK model or it's equivalent found in:
b) Vinegar, A., Jepson, G.W., Cisneros, M., Rubenstein, R. and Brock, W.J. (2000): Setting Safe Acute Exposure Limits for Halon Replacement Chemicals Using Physiologically Based Pharmacokinetic Modeling, Inhalation Toxicology, 12:751-763.Based on constant exposure level for duration of exposure.
c)NFPA 2001 Standard on Clean Agent Fire Extinguishing Systems, 2004 Edition, National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts, Feb. 2004.
d) Based on Canine Data
e) Obtained from the manufacturer
f) Immediate descent at the maximum safe rate to the lowest practicable altitude is recommended for all unpressurized aircraft to minimize exposure to halogenated gases and reduces the hazards of low- oxygen hypoxia resulting from the agent displacing oxygen from the air in the compartment. This holds for ventilated and unventilated compartments.
g) Halon Data is provided for comparison only. See AC20-42C for current Halon Guidance.

Use equation A1 to find the maximum safe W/V ratio for any halocarbon extinguisher to be used on an aircraft:

$$\left(\frac{W}{V}\right)_{Safe} = \left(\frac{1}{S \bullet A}\right) \bullet \frac{(C_{Safe})}{(100 - C_{Safe})} \qquad \text{(eqn A1)}$$

where A= Altitude correction factor for S

For pressurized aircraft, use the pressure altitude of 8,000 feet: A=1.346

For unpressurized aircraft, use the pressure altitude of 14,000 feet: A=1.702

V is the net volume of the space, calculated as the gross volume minus the volume of fixed structures, ft^3.

W is the maximum safe weight of the clean agent, lb for a volume V, **(if all extinguishers are discharged)**;

S is the specific volume of the agent at 70° F (21° C), ft^3/lb;
C_{Safe} is the FAA allowed clean agent concentration (% by volume)

$X_{1Bottle}$ is the minimum safe volume for 1 bottle

$(W/V)_{safe}$ is based on all hand extinguishers in the cabin

The minimum safe cabin volume is based on the weight of agent in all bottles in the aircraft cabin. It can be calculated as follows:

$$X_{AllBottles} = X_{1Bottle} \bullet \#Bottles$$

Table A3. Specific Volume of halocarbon agents

Agent	Specific Volume of Agent at 1 atm and 70deg F (ft^3/lb)
HCFC Blend B	2.597[a]
HFC-227ea	2.2075[a,b]
HFC-236fa	2.4574[a,b]
Halon 1211	2.2446? NEED NUMBER[c]

a) Obtained from the manufacturer.
b) NFPA 2001 Standard on Clean Agent Fire Extinguishing Systems, 2004 Edition, National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts, Feb. 2004.
c) for information only

This calculation includes an allowance for the normal leakage from a "tight" enclosure due to agent expansion.

This minimum safe cabin volume for unventilated aircraft is to be used for poorly ventilated aircraft or compartments with an air change time of 6 minutes and greater, and when graphs for ventilated aircraft are not available for a particular agent.

A-8.3.3 CALCULATION BASIS FOR THE MAXIMUM SAFE HALOCARBON WEIGHT TO VOLUME RATIOS FOR VENTILATED AIRCRAFT

The selector graphs were developed by applying pharmacokinetic modeling of blood concentration data to perfect mixing agent decay curves. The methodology used to develop the selector curves is described in reference:

Speitel, Louise C. "Setting Safe Acute Exposure Limits for Dissipating Gaseous Halon and Halocarbon Extinguishing Agents in Ventilated Compartments" Federal Aviation Administration: Report to be published.

Appendix B:

Table B1 ***Effective and Gross Weights of Halocarbon and Water Extinguishers***

Listing	Fire size Class A, Panel Fire	Fire size Class A, Crib Fire	Fire size Class B Novice	Fire size Class B Experienced	Agent and Extinguishers*				
					Halon 1211	Water	HFC-236fa	HCFC BlendB	HFC-227ea
UL 5-B:C	N/A	N	5 sq ft	12.5 sq ft	Agent 2.5 lb Gross Wt. 3.7 lb		Agent 4.75 lb. Gross Wt. 9.5 lb.	Agent 5.2 lb Gross Wt. 9.6 lb	Agent 5.75 lb Gross Wt. 9.1 lb
UL 1-A:5-B:C	8 ft x 8 ft	72 members 2 x 2 x 20 in. 12 layers of 6	5 sq ft	12.5 sq ft	Agent 3.5 lb Gross 4.4 lb				
UL 1-A:10-B:C	8 ft x 8 ft	72 members 2 x 2 x 20 in. 12 layers of 6	10 sq ft	25 sq ft	Agent 9 lb Gross Wt. +16 lb		Agent 9.5 lb. Gross Wt. 21.81lb.	Agent 11 lb Gross Wt. 22 lb	
UL 2A	10 ft x 10 ft	112 members 2 x 2 x 25 in. 16 layers of 7	N/A	N/A		Agent 22 lb (2.5gal) Gross Wt. 28 lb.			
UL 2-A:10-B:C	10 ft x 10 ft	112 members 2 x 2 x 25 in. 16 layers of 7	10 sq ft	25 sq ft			Agent 13.3 lb. Gross Wt. 25.6 lb.	Agent 15.5 lb Gross Wt. 27 lb	
UL 2A-40 B:C	10 ft x 10 ft	112 members 2 x 2 x 25 in. 16 layers of 7	40 sq ft	100 sq ft	Agent 16 lb Gross Wt. 33 lb				

* Agent and extinguisher weights are extinguisher dependent. Extinguishing effectiveness is determined by test.

Table B2 ***(FOR COMMITTEE USE ONLY)***

The information in the table below is from: Hocking, M.B. (1998). *Indoor Air Quality:Recommendations Relevent to Aircraft Passenger Cabins*. American Industrial Hygiene Association Journal. 59:446-454.

Aircraft	Minimum Reported Air Changes Per Hour	Minutes for Air Change	Cabin Volume, m3	Cabin Volume, ft3
Boeing 737-100	26.1	2.30	120	4238
McDonald Douglas DC9-30	27.3	2.20	124	4379
Boeing 737-200	17.7	3.39	131	4626
McDonald Douglas DC9-50	18.8	3.19	148	5227
McDonald Douglass DC10-10	22.8	2.63	149	5262
Boeing 737-300 (42)	14.2	4.23	149	5262
Boeing 727-100	22.9	2.62	151	5333
Boeing 727-200	18.8	3.19	165	5827
McDonald Douglas DC9-80/MD80 (22)	19.7	3.05	173	6109
Boeing 757 (48)	15.6	3.85	276	9747
Boeing 767-200 (52)	10.3	5.83	319	11265
Airbus Industrie 310 (53)	9.7	6.19	334	11795
McDonald Douglas DC10-40 (35)	14.9	4.03	419	14797
Boeing 767-300 (-)	11.1	5.41	428	15115
Lockheed L1011-50	19.3	3.11	494	17445
Lockheed L1011-1/100	17.8	3.37	537	18964
Boeing 747 (26)	14.7	4.08	790	27899
	Avg.	**3.68**		

Volumes for Smaller Commercial Aircraft

Aircraft	Number of Seats	Cabin Volume, ft3
Embraer ERJ-135	37	968
Embraer Brasilia EMB-120	30	968
Saab-340A & 340B	33	1180
Fairchild Dornier 328	32	1183
DASH-8, 100&200 series	37	1328
Saab 2000	50	1860
Embraer ERJ-145	50	1872
CRJ-200	50	2015
CRJ-700	64	2682
DASH-8, 400 series	78	2740

Volumes for Aircraft that normally seat 6 to 8 passengers

Aircraft	Cabin Volume, ft3
Piper PA31T Cheyenne	151
Cessna Caravan II	152

Socata TBM-700	155	estimated by Pilatus
Raytheon Beechcraft King Air 90 & 100	179	79.6 for cockpit
Gulfstream Turbo Commander	184	six seater
Gulfstream Jetprop	184	
Sino Swearingen SJ30-2	190	
Cessna Corsair, Conquest I	193	
Cessna 421	217	
Cessna 414	226	
Rockwell Gulfstream Commander GC-1000	249	
Cessna Caravan 675	254	
Cessna Caravan Amphibian	254	
LearJet 31A	271	
Cessna Citation CJ1	300	
Raytheon Beechcraft King Air 200	303	includes bathroom and internal baggage
Raytheon Beechjet 400	305	95 for cockpit
VisionAire Vantage	310	
Raytheon Premier I	315	
Pilatus PC12	330	
Cessna Grand Caravan	340	
Cessna Citation CJ2	350	
Raytheon Beechcraft King Air 300/350	355	includes bathroom and internal baggage
LearJet 40	363	
Gulfstream G100	367	
LearJet 45/45XR	410	
LearJet 60	453	
Gulfstream G150	465	
Gulfstream G200	868	